COMMONWEALTH of VIRGINIA

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VIRGINIA DEPARTMENT OF HEALTH (VDH) GUIDELINE FOR ISSUANCE OF FISH-EATING ADVISORY DUE TO CONTAMINATION OF FISH WITH MERCURY

Mercury is a naturally occurring metal which is widespread and persistent in the environment. It exists in three forms: elemental or metallic mercury, inorganic mercury, and organic mercury. Elemental mercury is a silver-white liquid at room temperature that vaporizes readily when heated. Inorganic mercury compounds occur when mercury combines with elements such as chlorine, sulfur, or oxygen. Most inorganic compounds are powders or crystals. Organic mercury compounds occur when mercury combines with carbon. One organic form of mercury, methylmercury, is produced when a carbon and three hydrogen molecules are attached to the elemental mercury. Methylmercury is of particular concern because it can accumulate up the food chain in aquatic systems and can lead to high concentrations in predatory fish.

Uses of Mercury

Elemental mercury is used in thermometers, thermostats, switches, barometers, batteries, dental amalgam, and other products. Inorganic mercury compounds are commonly used in electrical equipment (e.g., switches and lamps), and in medicinal and skin care products, such as antiseptic creams and ointments. Organic mercury compounds are used in industry as pigments in paints and as fungicides.

Sources of Mercury in the Environment

Mercury is released to the environment by both natural sources and human activities. Most of the mercury in air, water, and soil is inorganic mercury. This inorganic mercury can enter the air from deposits of ore that contain mercury, from burning fuels or garbage, and from emissions by factories that use mercury. Inorganic mercury may also enter water or soil from rocks that contain mercury, releases of water containing mercury from factories or water treatment facilities, and the disposal of wastes. Organic compounds of mercury may be released in the soil through the use of mercury-containing fungicides. Metallic mercury can evaporate easily into the air and be carried a long distance before returning to water or soil in rain or snow. Once mercury enters lakes, rivers, or oceans in any form, it is converted to methylmercury by microorganisms (bacteria and fungi) or by chemical reactions.

Fish absorb methylmercury directly from water and from eating smaller aquatic organisms that contain methylmercury. Although virtually all fish species contain at least trace amounts of methylmercury, larger predatory fish species have the highest concentrations. Methylmercury is tightly bound to proteins in all fish tissue, including muscle. There is no method of cooking or cleaning fish which will reduce the amount of mercury in a meal. Since almost all of the mercury in fish is in the form of methylmercury, the fish-eating advisory guideline is based on methylmercury.

Toxicity of Mercury

Evidence from human and animal studies indicates that the nervous system is sensitive to all forms of mercury. Exposure to high levels of all forms of mercury can permanently damage the brain, kidney, and developing fetus. Methylmercury is more harmful because more mercury in this form reaches the brain. Methylmercury is rapidly absorbed from the gastrointestinal tract (about 95%) and readily enters the adult and fetal brain where it accumulates and slowly converts to inorganic mercury. The exact mechanism by which mercury causes neurotoxic effects is not known, and data are not avail-available on how exposure to other forms of mercury affects methylmercury toxicity.

Acute high-dose exposure to methylmercury can result in adverse effects in several organ systems throughout the life span of humans and animals. Extensive data exist on the effects of methylmercury on the development of the brain in humans and animals. The most severe effects reported in humans were seen following high-dose acute poisoning episodes in Japan and Iraq. The outbreak of neurological disorders in Japan in the 1950s was attributed to the consumption of fish contaminated with methylmercury. Industrial waste containing inorganic mercury had been discharged into Minimata Bay and was converted by microorganisms into methylmercury. This resulted in contamination of fish, a major food source to the surrounding population. In this incident 700 people died and approximately 9,000 suffered severe health effects. A similar epidemic of neurological disorders occurred in Iraq in 1971 as a result of consumption of contaminated food. In this case flour was ground from grain treated with methylmercury fungicide. This incident affected more than 6,000 people. The health effects on brain functioning included irritability, mental retardation, shyness, tremors, cerebral palsy, deafness, and blindness in individuals who were exposed *in utero,* and sensory and motor impairment in exposed adults.

Chronic, low-dose prenatal methylmercury exposure from maternal consumption of fish has been associated with more subtle endpoints of neurotoxicity in children. Results from the three large epidemiological studies (the Faroe Islands, Seychelles Islands, and New Zealand studies) have added substantially to the body of knowledge on brain development following long-term exposure to small amounts of methylmercury. The Faroe Islands study reported associations between low-dose prenatal methylmercury exposure and children's performance on standardized neurobehavioral tests, particularly on the tests of attention, fine motor functions, confrontational naming, visual-spatial abilities (*e.g.,* drawing), and verbal memory. The Seychelles Islands study did not report such associations. The New Zealand study also observed associations, as did the large pilot study conducted in the Faroe Islands.

There is evidence in humans and animals that exposure to methylmercury can have adverse effects on the developing and adult cardiovascular system (blood pressure regulation, heart rate variability, and heart disease). There is also evidence in animals that the immune and reproductive systems are sensitive targets for methylmercury.

VDH had historically used the Food and Drug Administration's (FDA) action level of one part per million (ppm) for issuing fish consumption advisories for mercury. However, recently, the National Academy of Sciences (NAS) has produced a review of the toxicity of methylmercury and has recommended a reference dose (RfD) of 0.0001 milligrams per kilograms per day (mg/kg/day) for sensitive and nonsensitive populations. The RfD is an estimate of a daily exposure to the human population (including sensitive subpopulations) that is likely to be without appreciable risk of deleterious effects during a lifetime. In view of the NAS recommendation, VDH has revised its existing guidelines for issuing fish consumption advisories due to mercury contamination.

Derivation of Acceptable Concentration of Methylmercury in Fish

The formula for calculating an acceptable concentration, corresponding to a recommended two meals per month of methylmercury in edible fish tissue, for protecting fish consumers from noncancer health effects is as follows:

$$C = \frac{RfD \times BW \times T}{MS \times NM}$$

Where:

C = acceptable concentration of methylmercury in edible portions of fish in milligrams per kilograms (mg/kg).

RfD = reference dose (RfD) for methylmercury in milligrams per kilogram per day (0.0001 mg/kg/day).

BW = consumer adult body weight in kilograms (70 kg). A body weight of 70 kilograms for the average adult male is widely accepted by many regulatory agencies for risk assessment and establishing guidelines and standards for chemical exposure.

T = time period 30 days (days/month). Time period of 30 days/month was used to calculate fish meal consumption limits, in a 30-day period as a function of meal size.

MS = average fish meal size of 8 ounces (oz) or 0.227 kg. Meal size is defined as the amount of fish (in kilograms) consumed at one meal. An 8-oz or 0.227 kg meal size was assumed.

NM = number of allowable meals per month (2 meals/month). Number of meals consumption limit is expressed as the maximum allowable fish meals in a 30-day time period. These are based on the total dose allowable over a 1-month period (based on the the RfD).

Substituting for assumptions in the above equation, an acceptable methylmercury concentration of 0.5 mg/kg in edible fish tissue was derived.

$$C = \frac{0.0001 \text{ mg/kg/day} \times 70 \text{ kg} \times 30 \text{ day/month}}{0.227 \text{ kg/meal} \times 2 \text{ meals/month}}$$

$$= 0.4625 \text{ mg/kg} \approx 0.5 \text{ mg/kg}$$

Conclusion

Based on the above calculation, VDH would use 0.5 mg/kg or 0.5 ppm of methylmercury in fish as the trigger level for the issuance of a fish-eating advisory. When individual fish data are available, if 50% of fish samples exceed the guidance levels, this would trigger an advisory. VDH will use a four-tiered approach when issuing a fish- eating advisory.

- Average fish tissue concentrations ranging from non-detectable to below 0.5 ppm will not warrant issuance of a fish-eating advisory.

- When the average concentrations in fish range from 0.5 ppm to below 1 ppm, VDH will recommend limiting consumption of contaminated species to two, 8-oz meals per month.

- When the average concentration in fish range from 1 ppm to below 2.0 ppm, VDH will recommend limiting consumption of contaminated species to one, 8-oz meal per month.

  When the average concentrations in fish exceed 2.0 ppm, VDH will recommend that contaminated fish should not be consumed.

VDH would also recommend that pregnant women, nursing mothers, and young children should not consume fish contaminated with methylmercury at concentrations above 0.5 ppm.

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